PHYTOPLANKTON CONDITIONS IN THE NANTICOKE AREA OF LAKE ERIE, 1969-1971

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Ministry of the Environment
Ontario

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by

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SUMMARY

Changes in abundance and seasonal composition of standing stocks of phytoplankton were evaluated at eight fixed stations in 1969 and 1970 and at nine stations in 1971. Water clarity and chlorophyll levels were also assessed.

Quantitative measurements were recorded as areal standard units. Values were lowest in 1969 and highest in 1970 for all stations. Higher standing stocks of phytoplankton were recorded at the off-shore locations than in coastal waters. At the former sampling sites two distinct maximal periods of phytoplankton development occurred; the first materialized during May and June while the second was apparent during the latter part of August and early September. In contrast, at the in-shore stations, the bimodal pattern was not observed although a well-defined mid-summer maximum was detected in 1970.

Major changes in species composition were not detected from one year to the next. Generally, diatoms prevailed during the early spring and late autumn seasons although small to moderate numbers of flagellated algae (i.e. Chrysophyceae, Cryptophyceae and Dinophyceae) were encountered. During the late spring and early summer the flora consisted mainly of cryptophycean and green algae and diatoms. The late summer and early fall samples were characterized, for the most part, by blue-green and green algae; however, low numbers of flagellates (i.e. Dinophyceae and Cryptophyceae) and diatoms were identified and enumerated.

Water clarity, as recorded by Secchi disc readings was higher at off-shore stations, although chlorophyll a concentrations were homogeneous throughout the study area. The chlorophyll a and Secchi disc data were described by a near-hyperbolic relation. Values for the near-shore stations formed a group of points somewhat removed from the established relationship indicating that higher turbidity levels were reducing water clarity conditions in these coastal waters. It was suggested that future changes in water clarity will result in shifts in the positions of the chlorophyll-Secchi disc relationships for each station.

It appeared that high turbidity at near-shore stations limited light penetration and therefore reduced algal densities. This would account for the consistent differences in mean areal standard unit values between coastal and off-shore stations.

INTRODUCTION

Extensive development in the Nanticoke area of Lake Erie has been proposed by Texaco Canada Limited, the Hydro Electric Power Commission and the Steel Company of Canada (Stelco). As part of pre-operational biological water quality data, phytoplankton samples were collected to complement information on physico-chemical conditions, zooplankton, bottom fauna and fish populations. This report evaluates the abundance and changes in seasonal composition of standing stocks of phytoplankton at eight locations in 1969 and 1970 and at nine sampling sites in 1971. Also, complementary data on water clarity and chlorophyll levels in the Nanticoke area are reported.

METHODS

Field Methods

In 1969, 1970 and 1971 samples were collected at eight stations (Figure 1) in the Nanticoke area of Lake Erie for phytoplankton analyses. Samples were secured as composites through the euphotic zone (zone of significant light penetration measured as twice the Secchi disc) or at 1 metre of depth approximately every two weeks during the ice-free seasons. In 1971, an additional station (Station 1,040) in the immediate vicinity of the proposed thermal discharge from the Nanticoke Generating Station was sampled.

All samples were preserved with Lugol's iodine at the time of sampling and transported to the Ministry of the Environment's laboratories in Toronto for analyses.

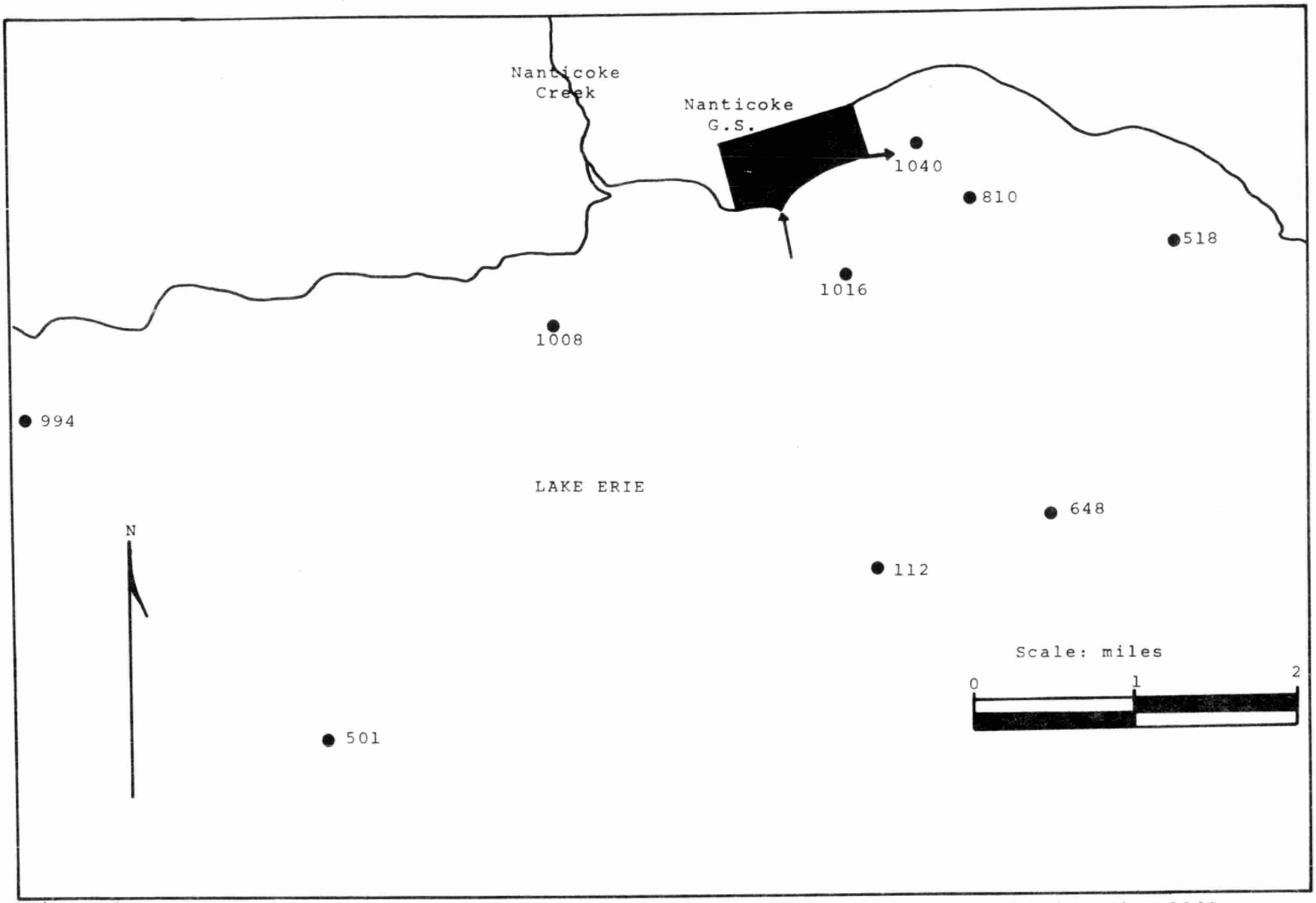

Figure 1: Location of phytoplankton sampling stations in the Nanticoke area of Lake Erie, 1969, 1970 and 1971.

In 1970 and 1971 data on water clarity (Secchi disc recordings and turbidity measurements) were obtained at each station as part of an on-going water quality monitoring programme. In 1971 only, samples for chlorophyll a concentrations were secured from similar depths as those samples for phytoplankton. The chlorophyll samples were preserved with 1-ml of a 2% magnesium carbonate solution and were subsequently delivered to Toronto.

Laboratory Methods

The algal samples were concentrated by allowing the cells to settle for 72 - 96 hours, and the overlying liquid was then syphoned or decanted. Subsequently, the cells were re-suspended in the concentrate and a 1-ml aliquot was transferred into a Sedgwick Rafter counting cell. Most of the algal forms were identified to genus at a magnification of 200x. When identification to species of forms other than diatoms were required, wet mounts were prepared and examined at 440x or 970x. In some cases, identifications were facilitated by dissolution of the potassium iodide: iodine stain with sodium thiosulphate. Quantitative results were expressed as areal standard units per millilitre (a.s.u. per ml). One areal standard unit is equal to an area of 400 square microns. The areal standard unit method was employed because it affords a degree of quantitative comparability from one sample to another in measuring standing stocks of algae and because it is extremely helpful when relating algal levels to problems associated with biological quality of the water.

The Bacillariophyceae (diatoms) were speciated by acid-digestion of a 15-ml portion of the concentrate followed by mounting in Hyrax. These algae were identified at a magnification

of 970x or 1200x and counted by starting at one edge of the cover-slip and scanning one or more rows across the mount. Valves were counted as one-half frustule; broken valves were not included in the counts. Conversion to areal standard unit values was accomplished by direct proportion. Taxonomic references included Prescott (1951), Patrick and Reimer (1966), Tiffany and Britton (1952), Sieminska (1964).

Turbidity analyses involved standard techniques utilized by the Chemistry I Section of the Ministry of the Environment. Chlorophyll determinations were completed following the methods of Brydges (1971).

RESULTS

Water Clarity and Chlorophyll a Concentrations

Information on water clarity (Secchi disc readings and turbidity levels) and chlorophyll a concentrations is presented in Table 1. A close examination of the data indicates that clearer water quality conditions prevailed at the three off-shore stations than at the five near-shore sampling sites. In general, chlorophyll a concentrations, at least during the ice-free period of 1971, were homogenous throughout the study area ranging from a low of 0.7 µg/l at Stations 501, 994 and 1,008 to a high of 3.9 µg/l at Station 810.

Standing Stocks of Phytoplankton

Table 2 summarizes the minimum, maximum and mean areal standard unit values for the station samples. Mean a.s.u. values were lowest in 1969 and highest in 1970 for all stations. Additionally, higher standing stocks of phytoplankton were recorded at the three off-shore stations than at the six near-shore sampling locations.

Table 1. Summary of Secchi disc (m), turbidity (Jackson Turbidity Units) and chlorophyll a concentrations (µg/l) from selected stations in the Nanticoke area of Lake Erie.

		Secchi disc			Turbidity			Chlorophyll a		
		Range	Mean	No. Analyses	Range	Mean	No. Analyses	Range	Mean	No. Analyses
In-shore Stations										
518	1970	1.0-4.4	2.9	4	1.5-15.0	6.0	4	-	-	-
	1971	1.2-3.7	2.6	7	2.2-7.0	4.5	7	6.6-3.2	1.7	14
810	1970	1.9-4.5	2.6	4	2.9-6.0	4.2	4	-	-	-
	1971	1.0-4.0	2.7	7	1.8-8.0	5.5	7	0.8-3.9	1.7	14
994	1970	1.1-4.2	2.6	4	1.5-5.1	2.6	4	-	-	-
	1971	2.0-5.0	3.1	7	2.5-8.5	5.8	7	0.7-2.9	1.7	7
1,008	1970	1.0-3.0	2.3	4	1.5-5.4	3.1	4	-	-	-
	1971	2.0-4.3	2.6	7	2.0-8.5	4.0	7	0.7-2.6	1.8	7
1,016	1970	1.8-4.4	3.0	4	2.0-4.1	3.0	4	-	-	-
	1971	2.0-4.5	2.9	7	1.8-8.5	4.4	7	0.9-3.5	1.7	11
1,040	1970	-	-	-	-	-	-	-	-	-
	1971	-	-	-	-	-	-	-	-	-
Off-shore Stations										
112	1970	2.2-7.3	4.3	4	1.4-3.4	2.3	4	-	-	-
	1971	3.5-9.0	6.0	7	1.5-8.0	3.0	7	0.8-3.1	1.8	7
501	1970	2.0-7.8	4.8	4	1.6-3.9	2.3	4	-	-	-
	1971	3.5-8.4	5.7	7	1.8-8.2	3.2	7	0.7-3.5	1.7	7
648	1970	1.8-5.6	4.4	4	1.4-3.1	2.3	4	-	-	-
	1971	2.2-7.9	5.4	7	1.5-9.0	3.2	7	0.8-3.2	1.6	7

Table 2. Summary of phytoplanktonic data collected from nine sampling sites in the Nanticoke area of Lake Erie. All values are expressed as areal standard units per millilitre.

	1969			1970			1971		
	Range	Mean	No. Analyses	Range	Mean	No. Analyses	Range	Mean	No. Analyses
In-shore Station									
518	41-733	244	14	125-1,838	597	14	119-728	451	13
810	71-479	242	15	137-3,684	675	14	155-1,104	442	13
994	36-903	269	16	172-2,638	668	14	86-1,349	445	13
1,008	38-368	178	16	203-2,157	595	12	115-882	380	13
1,016	39-630	163	15	191-1,607	540	14	199-821	439	13
1,040	-	-	-	-	-	-	171-930	397	13
Off-shore Stations									
112	25-1,162	345	14	163-2,275	819	14	101-1,023	497	13
501	43-1,191	330	15	84-2,378	700	14	240-1,168	556	13
648	6-986	346	15	142-2,783	812	13	175-1,229	486	13

Changes in the season of development and composition of the major taxonomic groupings (i.e. Bacillariophyceae, Dinophyceae, Chlorophyceae, Cryptophyceae, Chrysophyceae and Myxophyceae) are presented in Figures 1 through 9 of the Appendix. At the off-shore sampling sites two distinct maximal periods of phytoplankton development occurred; the first materialized during the spring months while the second was apparent during the latter part of August and early September (Figures 1, 2 and 4 of the Appendix). In contrast, at the in-shore stations regular bimodal patterns in phytoplankton development were not apparent although a well-defined mid-summer maximum was detected in 1970 (Figures 3 and 5 through 9 of the Appendix).

During each season, similar species were recorded throughout the study area. Major changes in species composition were not detected from one year to the next. Generally, bacillariophycean (i.e. of diatoms) and cryptophycean algae predominated during the early spring and late autumn seasons although small to moderate numbers of chlorophycean (i.e. green), dinophycean and chrysophycean algae were encountered. During the late spring and early summer the flora consisted mainly of cryptophycean and green algae and diatoms. The late summer and early fall samples were characterized, for the most part, by blue-green and green algae; however, low numbers of Dinophyceae, Cryptophyceae and diatoms were enumerated and identified.

Specifically, during May and early June the most important forms encountered at all locations were the diatoms Stephanodiscus spp., Melosira Binderana Kütz., Asterionella formosa Hass. and Synedra spp. Additionally, moderate numbers of the cryptophycean algae Cryptomonas spp. and Rhodomonas minuta Skuja, the dinophycean alga Peridinium spp.,

the chrysophyte Dinobryon spp. and the green Chlamydomonas spp. were observed.*

During the latter part of the spring and early summer when standing stocks of phytoplankton at all locations were relatively low, a variety of species representing a number of taxonomic groups were found. The most important species for this period included the diatom Fragilaria crotonensis Kitt., the cryptophycean forms Cryptomonas spp. and R. minuta and the chlorophycean algae Oocystis Borgei Snow, Chlamydomonas spp. and Coelastrum spp.

Highest numbers of algae usually materialized each year during the latter part of August and early September although levels were never high enough to constitute a "water-bloom" condition. Standing stocks were dominated by the myxophycean (blue-green) algae Chroococcus spp., Aphanocapsa spp., Aphanothece spp. and Anabaena spp. and green algae including Chlamydomonas spp., Cosmarium spp., Oocystis spp., Pediastrum spp. and Sphaerocystis schroeteri Chodat. Of some interest is that a single dinophyte, Ceratium hirundinella (O.F. Müell.) Dujardin persisted during this period. F. crotonensis and A. formosa were the most commonly encountered diatoms while Cryptomonas spp. and R. minuta were the most important cryptophytes.

In October and November when a.s.u. values throughout the study area were decreasing, the flora consisted of F. crotonensis, Stephanodiscus astraea (Ehr.) Grun., Stephanodiscus spp, A. formosa, Cryptomonas spp. and R. minuta. Additionally, O. Borgei, Chlamydomonas spp., Coelastrum spp., Pediastrum spp. and S. schroeteri were regularly encountered in low to moderate numbers.

*For purposes of future comparisons, the highest a.s.u. values for the most important species are provided in Table 1 of the Appendix.

DISCUSSION

The major purpose of this report is to document background data on water clarity and phytoplanktonic communities in the Nanticoke area and to synthesize the information to permit future comparisons should water quality changes result following thermal discharges.

In order to establish "bench mark" water clarity conditions we incorporated data on chlorophyll a concentrations and Secchi disc readings for the eight sampling stations into a near-hyperbolic relation for approximately sixty lakes including the Great Lakes (Figure 2 after Brown 1972). As indicated in Figure 2, eutrophic or enriched lakes which are characterized by high chlorophyll a concentrations and reduced water clarity are situated along the vertical axis of the hyperbola. On the other hand, oligotrophic or nutrient-poor waters have low chlorophyll a levels, allow significant light penetration and lie along the horizontal limb. Data for mesotrophic lakes would be located in the middle section of the curve. Chlorophyll a levels and Secchi disc depth for the three off-shore stations (i.e. Stations 112, 501 and 648) are located in close proximity to data collected from the Eastern Basin of Lake Erie by personnel associated with the Ministry of the Environment's water quality monitoring programme (Figure 2). Values for the near-shore stations form a group somewhat below the established relationship. As chlorophyll levels were usually homogenous throughout the study area (Table 1), the position of the near-shore sampling locations relative to the off-shore sites relates primarily to the higher turbidity levels recorded at the former locations (Table 1). It is suggested that future changes in water clarity could result in corresponding shifts in the position of the chlorophyll-Secchi disc relationship.

On initial examination, a good deal of variability in mean areal standard unit values appears to exist from one year to the next at each station (Table 2). For example, mean values

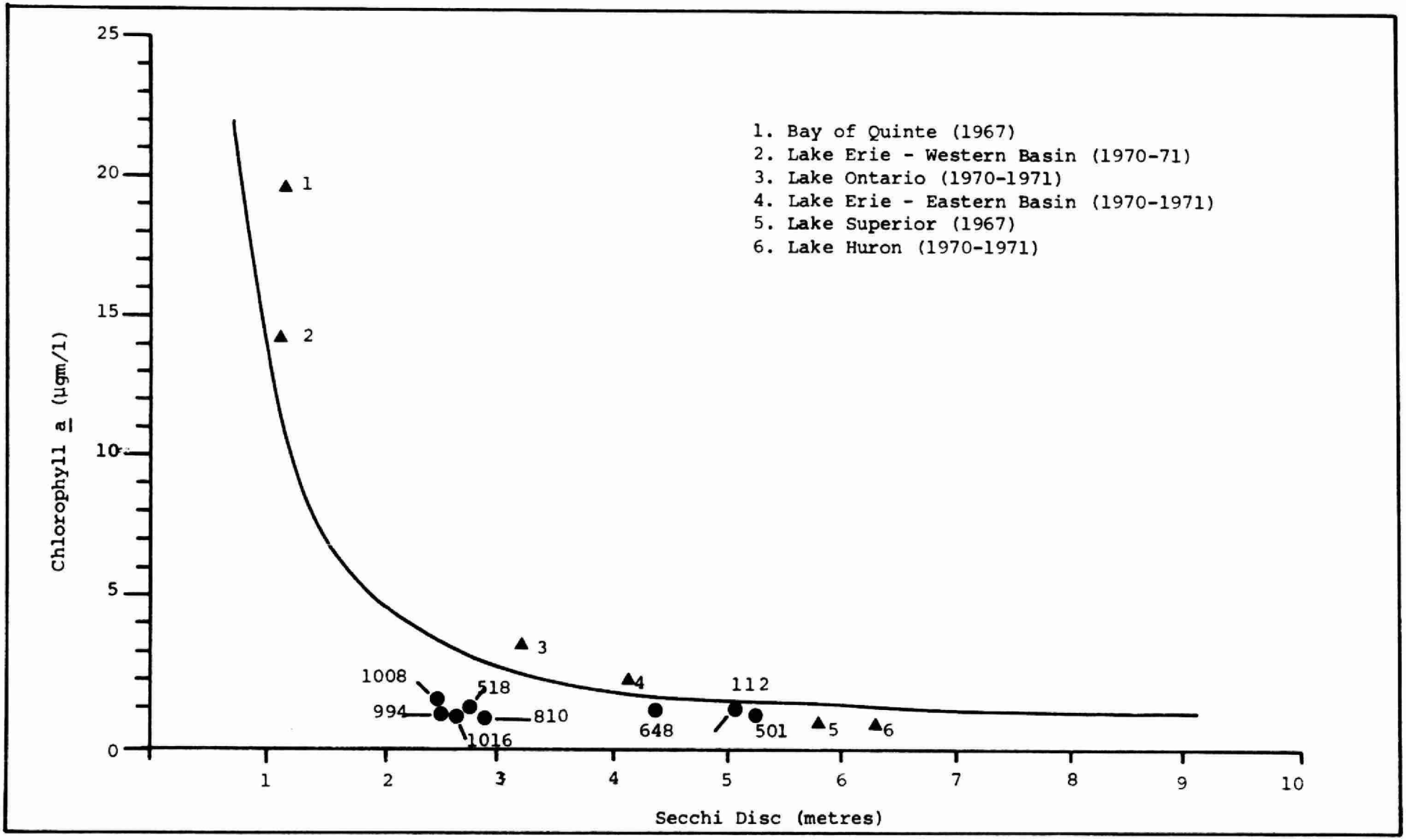

Figure 2: Chlorophyll - Secchi disc relationships for selected Great Lakes. Data for eight stations in the Nanticoke area of Lake Erie have been incorporated into the curve.

throughout the study area in 1970 were 2-2.5 times higher than in 1969. However, a consideration of Table 3 reveals that phytoplankton populations for the three study years were of the same order of magnitude as those recorded from Grand Bend and Dunnville (municipalities located on the shorelines of oligotrophic and oligo-mesotrophic waters, respectively), yet significantly lower than those recorded from the Union Water Treatment Plant on the northern shoreline of the enriched Western Basin of Lake Erie and from Lindsay where potable water is obtained from the highly productive Scugog River.

Of some interest is that standing stocks of phytoplanton were always higher at the off-shore stations than at the near-shore sampling locations. In contrast, Nalewajko (1967) and Munawar and Nauwerck (1970) reported that phytoplankton stocks and species composition in the coastal waters of Lake Ontario differed from those of the more central areas of the lake. For example, Nalewajko (1967) found that algae were two to three times as abundant close to shore with S. tenuis Hust. accounting for 18 to 51% of the total numbers while off-shore, S. tenuis accounted for only 1.8 to 10% of the total numbers while Melosira islandica O. Müell. and A. formosa were the most prominent species. Assuming that levels of important plant nutrient such as phosphorus and nitrogen are higher in the inshore area of Nanticoke, it is logical to argue that greater plankton production might be anticipated at the near-shore sites than at the off-shore locations. It is apparent, however, that some factor other than nutrients is limiting algal stocks in the coastal waters. The author suggests that the high turbidity levels in the near-shore waters have a strong impact on algal densities and account for the consistent differences in mean areal standard unit values between the respective sampling sites.

Table 3. Summary of phytoplanktonic data collected from various sources during the ice-free periods of 1969, 1970 and 1971. All results are expressed as areal standard units per millilitre.

Municipality	Source	Mean areal standard units per millilitre		
		1969	1970	1971
Nanticoke Station 112	Lake Erie	345	819	497
Nanticoke Station 501	Lake Erie	330	700	556
Nanticoke Station 518	Lake Erie	244	597	451
Nanticoke Station 648	Lake Erie	346	812	486
Nanticoke Station 810	Lake Erie	242	675	442
Nanticoke Station 994	Lake Erie	269	668	445
Nanticoke Station 1008	Lake Erie	178	595	380
Nanticoke Station 1016	Lake Erie	163	540	439
Nanticoke Station 1040	Lake Erie	-	-	397
Dunnville	Lake Erie	651	632	643
Union	Lake Erie	5,161	5,605	4,919
Grand Bend	Lake Huron	154	205	452
Lindsay	Scugog River	17,743	23,012	11,624

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A P P E N D I X

Figure 1: Seasonal changes in phytoplankton abundance and species composition at Station 112 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

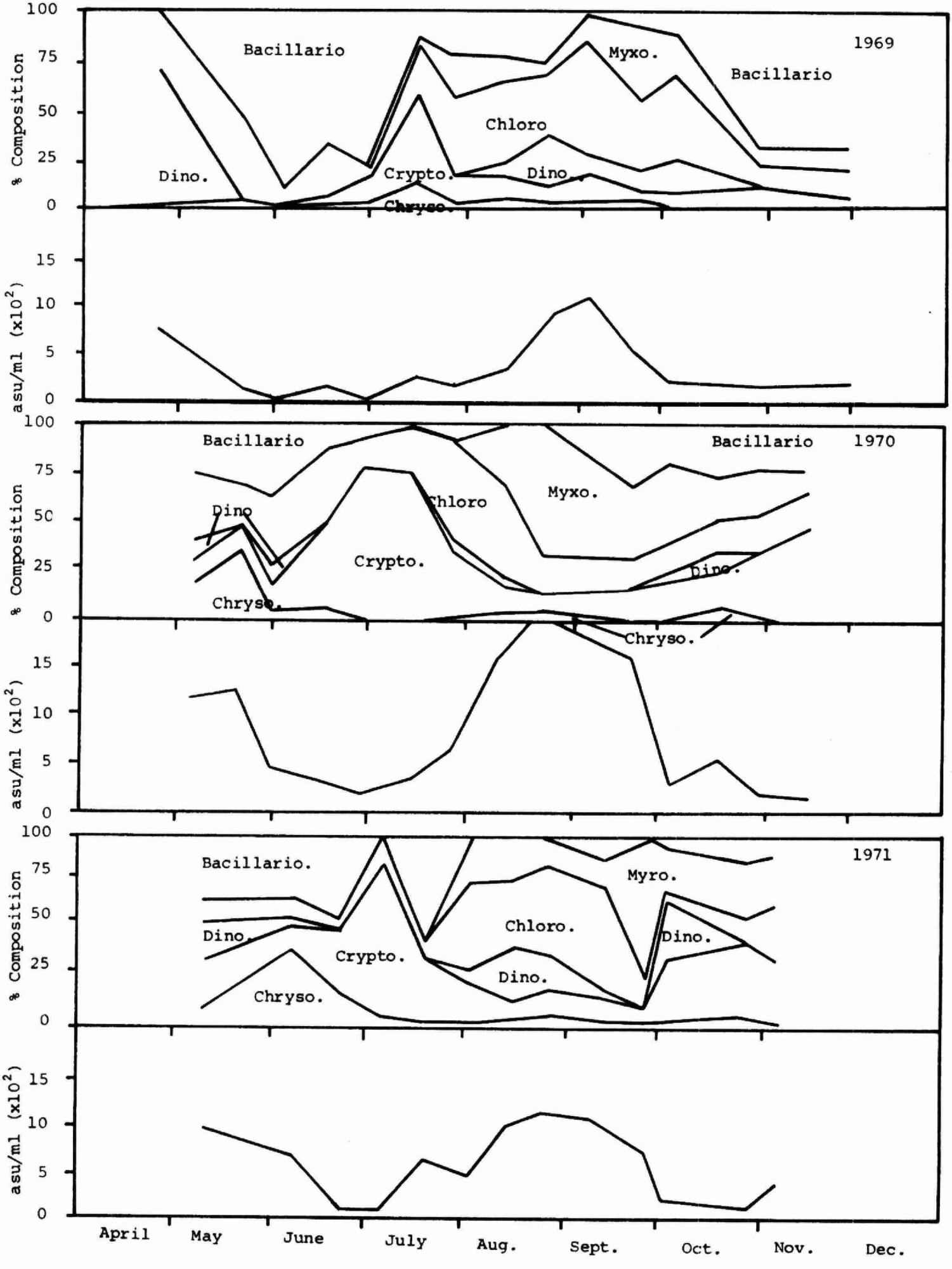
1969
Bacillario
Myxo.
Bacillario
Chloro
Dino.
Crypto.
Dino
Chryso.
% Composition
asu/ml (x10²)
1970
Bacillario
Bacillario
Myxo.
Chloro
Dino
Crypto.
Dino.
Chryso.
Chryso.
1971
Bacillario.
Myro.
Chloro.
Dino.
Dino.
Crypto.
Dino.
Chryso.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 2: Seasonal changes in phytoplankton abundance and species composition at Station 501 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

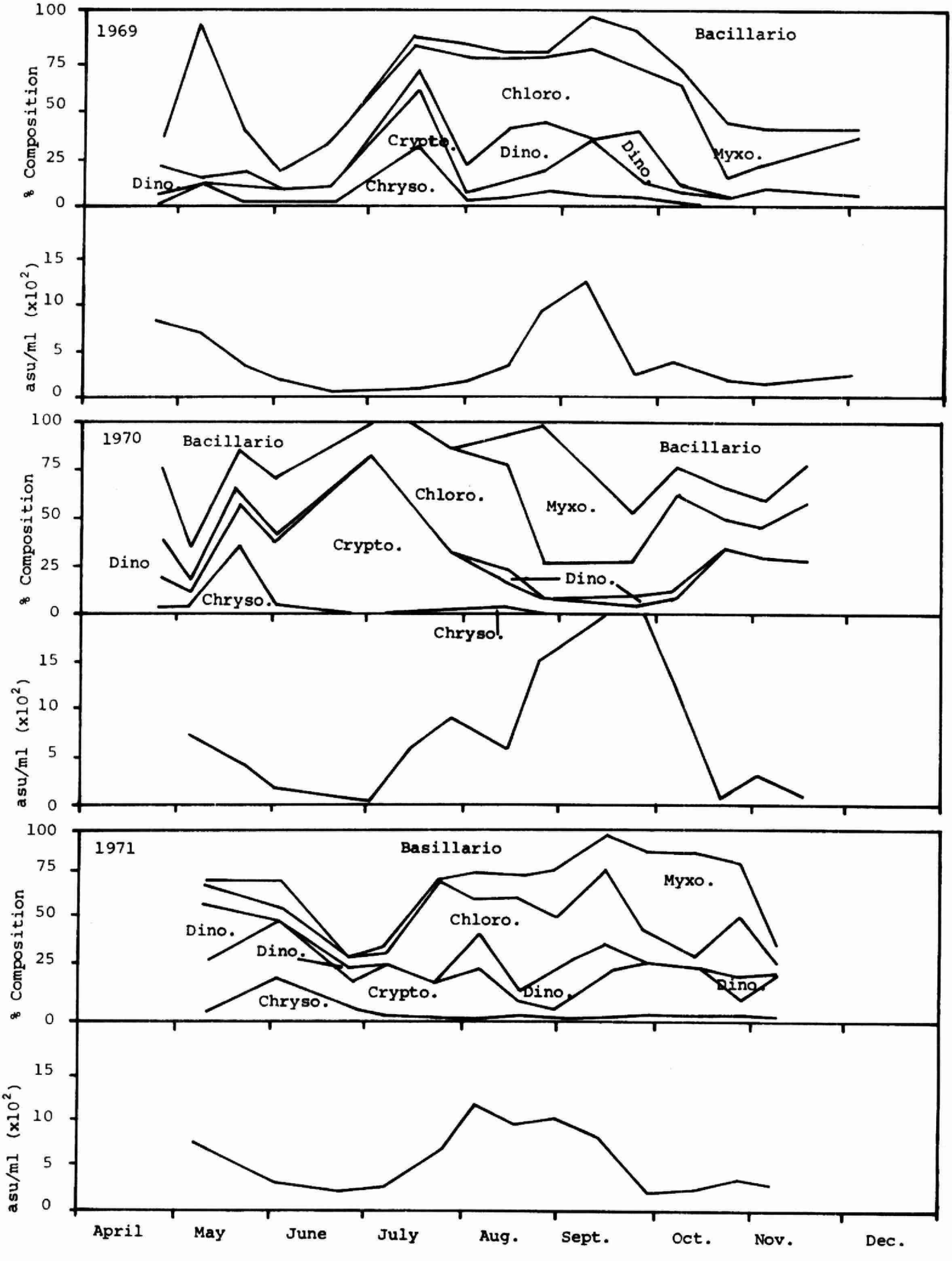
1969
Bacillario
Chloro.
Crypto.
Dino.
Dino.
Dino.
Myxo.
Chryso.
% Composition
asu/ml (x10²)
1970
Bacillario
Bacillario
Chloro.
Myxo.
Crypto.
Dino
Dino.
Chryso.
Chryso.
1971
Basillario
Myxo.
Chloro.
Dino.
Dino.
Crypto.
Dino.
Dino.
Chryso.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 3: Seasonal changes in phytoplankton abundance and species composition at Station 518 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

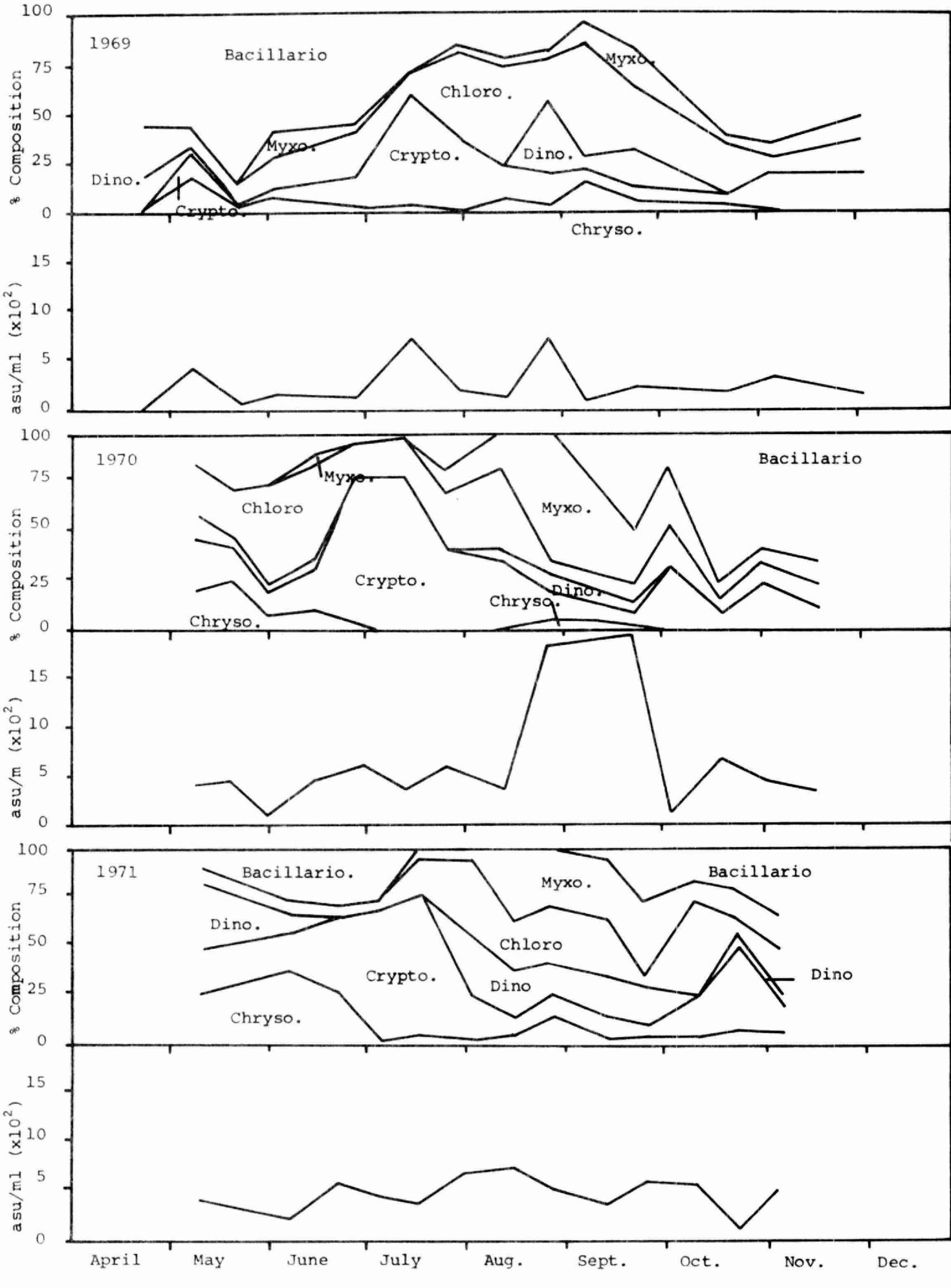
1969
Bacillario
Myxo.
Chloro.
Myxo.
Crypto.
Dino.
Dino.
Crypto.
Chryso.
% Composition
asu/ml (x10²)
1970
Bacillario
Myxo.
Chloro
Myxo.
Crypto.
Dino.
Chryso.
Chryso.
% Composition
asu/m (x10²)
1971
Bacillario.
Myxo.
Bacillario
Dino.
Chloro
Crypto.
Dino
Dino
Chryso.
% Composition
asu/ml (x10²)
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 4: Seasonal changes in phytoplankton abundance and species composition at Station 648 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

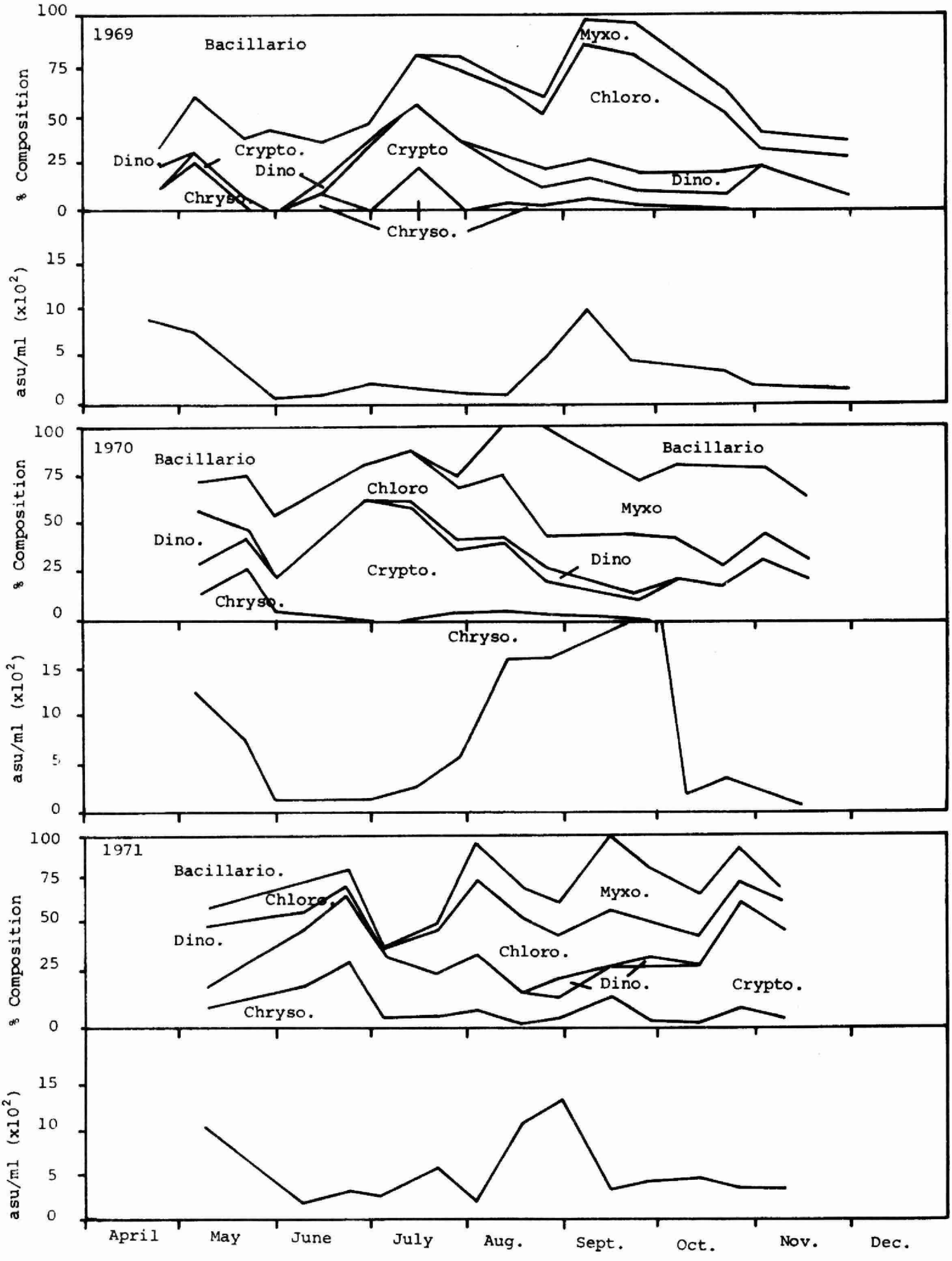
1969
Bacillario
Myxo.
Chloro.
Dino.
Crypto.
Dino
Crypto
Dino.
Chryso.
Chryso.
% Composition
asu/ml (x10²)
1970
Bacillario
Bacillario
Chloro
Myxo
Dino.
Dino
Crypto.
Chryso.
Chryso.
1971
Bacillario.
Chloro.
Myxo.
Dino.
Chloro.
Dino.
Crypto.
Chryso.
100
75
50
25
0
15
10
5
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 5: Seasonal changes in phytoplankton abundance and species composition at Station 810 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

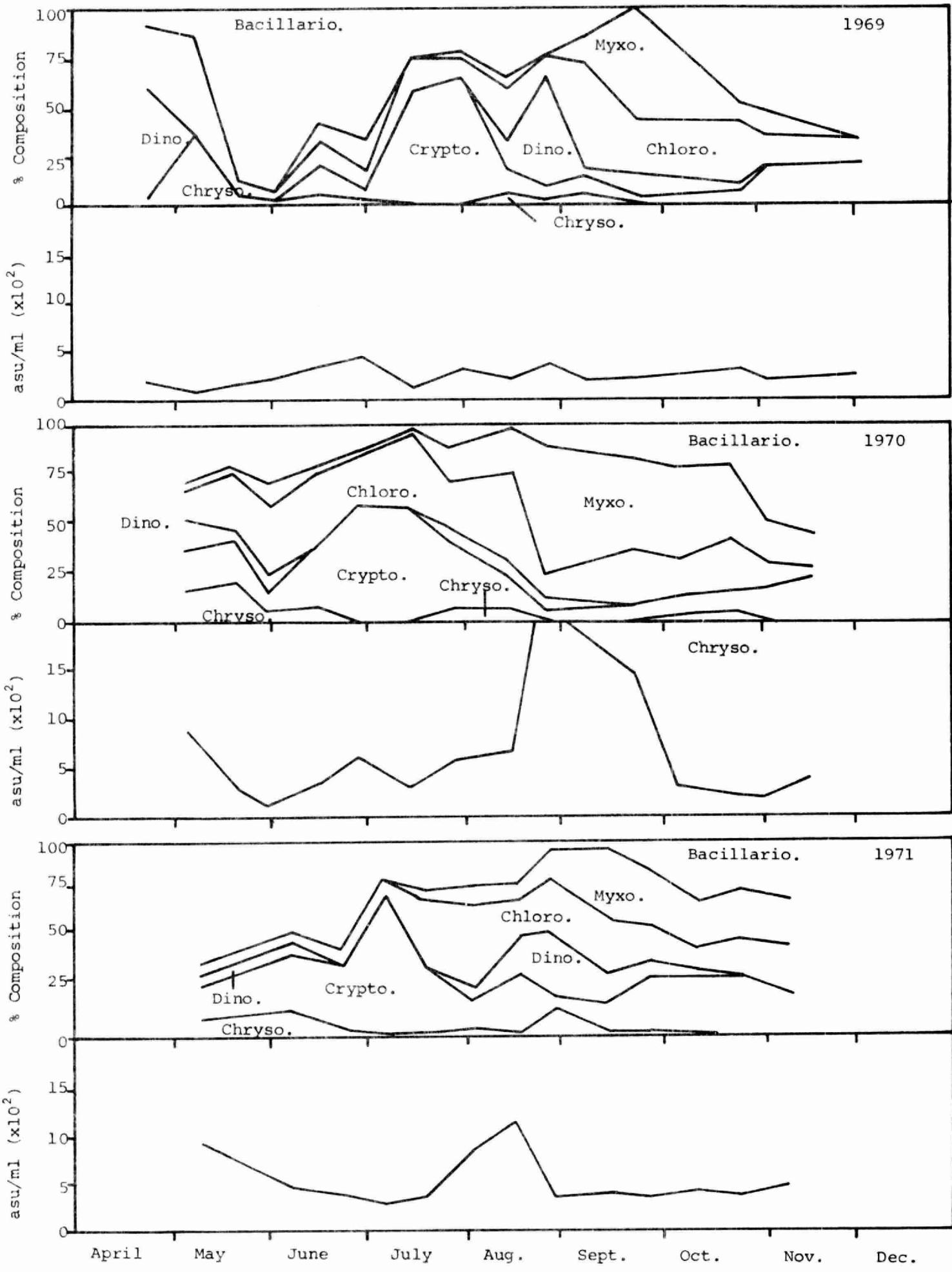
Bacillario.
1969
Myxo.
Dino.
Chryso.
Crypto.
Dino.
Chloro.
Chryso.
% Composition
asu/ml (x10²)
Bacillario.
1970
Chloro.
Myxo.
Dino.
Crypto.
Chryso.
Chryso.
Chryso.
Bacillario.
1971
Myxo.
Chloro.
Dino.
Crypto.
Dino.
Chryso.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 6: Seasonal changes in phytoplankton abundance and species composition at Station 994 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

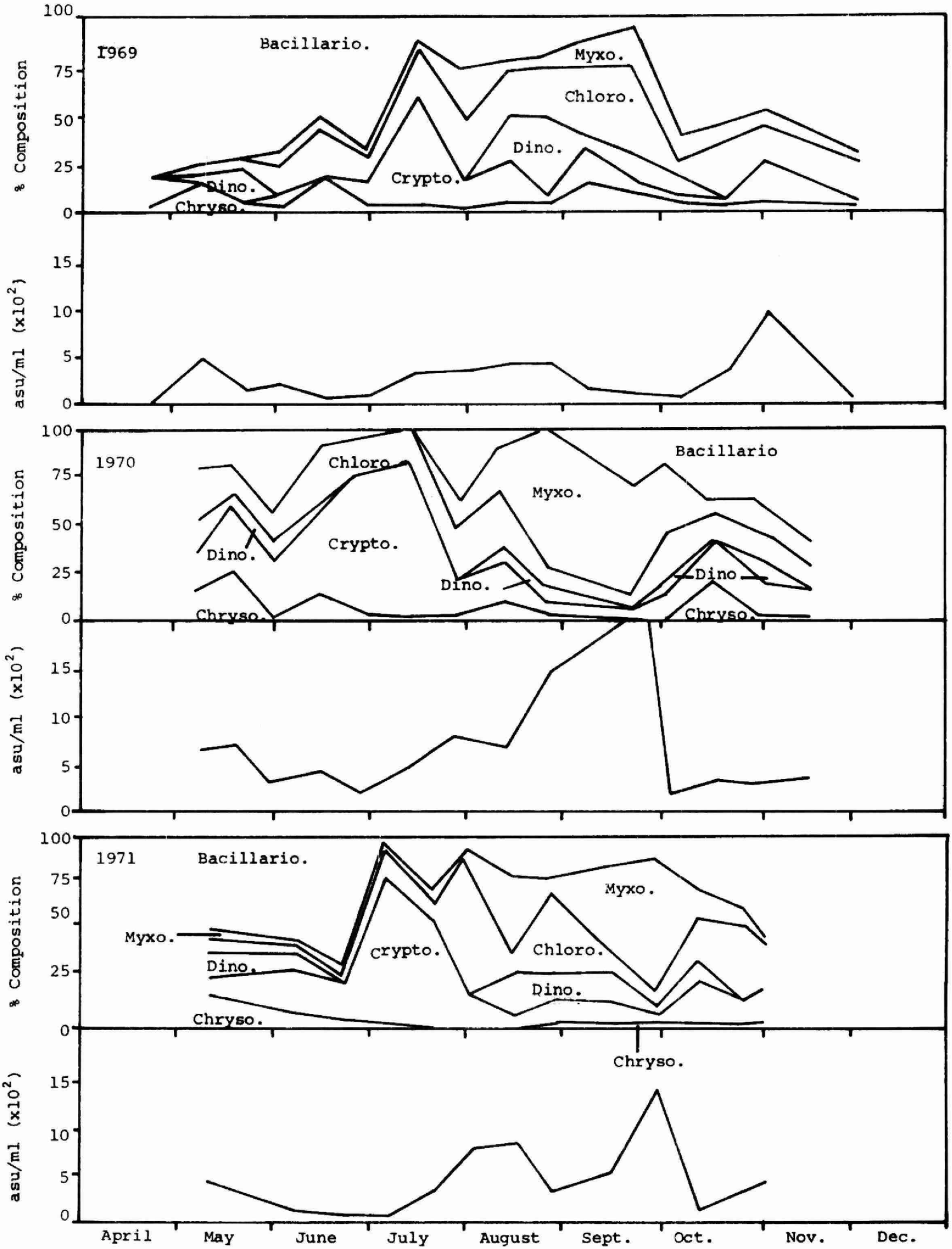
1969
Bacillario.
Myxo.
Chloro.
Dino.
Crypto.
Dino.
Chryso.
% Composition
asu/ml (x10²)
1970
Chloro.
Bacillario
Myxo.
Crypto.
Dino.
Dino.
Dino
Chryso.
Chryso.
1971
Bacillario.
Myxo.
Myxo.
Crypto.
Chloro.
Dino.
Dino.
Chryso.
Chryso.
100
75
50
25
0
15
10
5
April
May
June
July
August
Sept.
Oct.
Nov.
Dec.

Figure 7: Seasonal changes in phytoplankton abundance and species composition at Station 1008 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

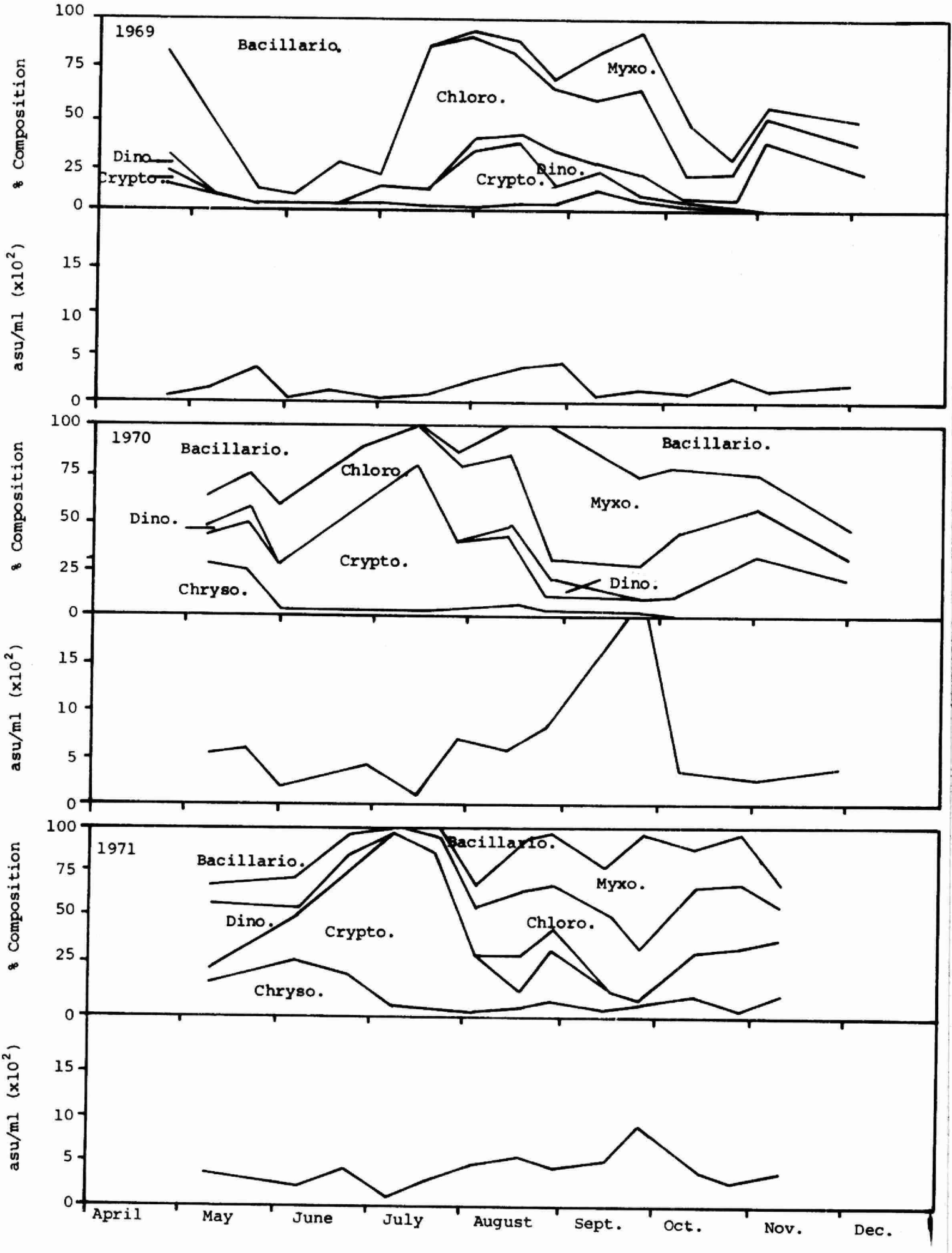
1969
Bacillario.
Chloro.
Myxo.
Dino.
Crypto.
Dino.
Crypto.
% Composition
asu/ml (x10²)
1970
Bacillario.
Chloro.
Bacillario.
Myxo.
Dino.
Crypto.
Chryso.
Dino.
1971
Bacillario.
Bacillario.
Myxo.
Dino.
Crypto.
Chloro.
Chryso.
100
75
50
25
0
15
10
5
April
May
June
July
August
Sept.
Oct.
Nov.
Dec.

Figure 8: Seasonal changes in phytoplankton abundance and species composition at Station 1016 in the Nanticoke area of Lake Erie. Data are presented for 1969, 1970 and 1971.

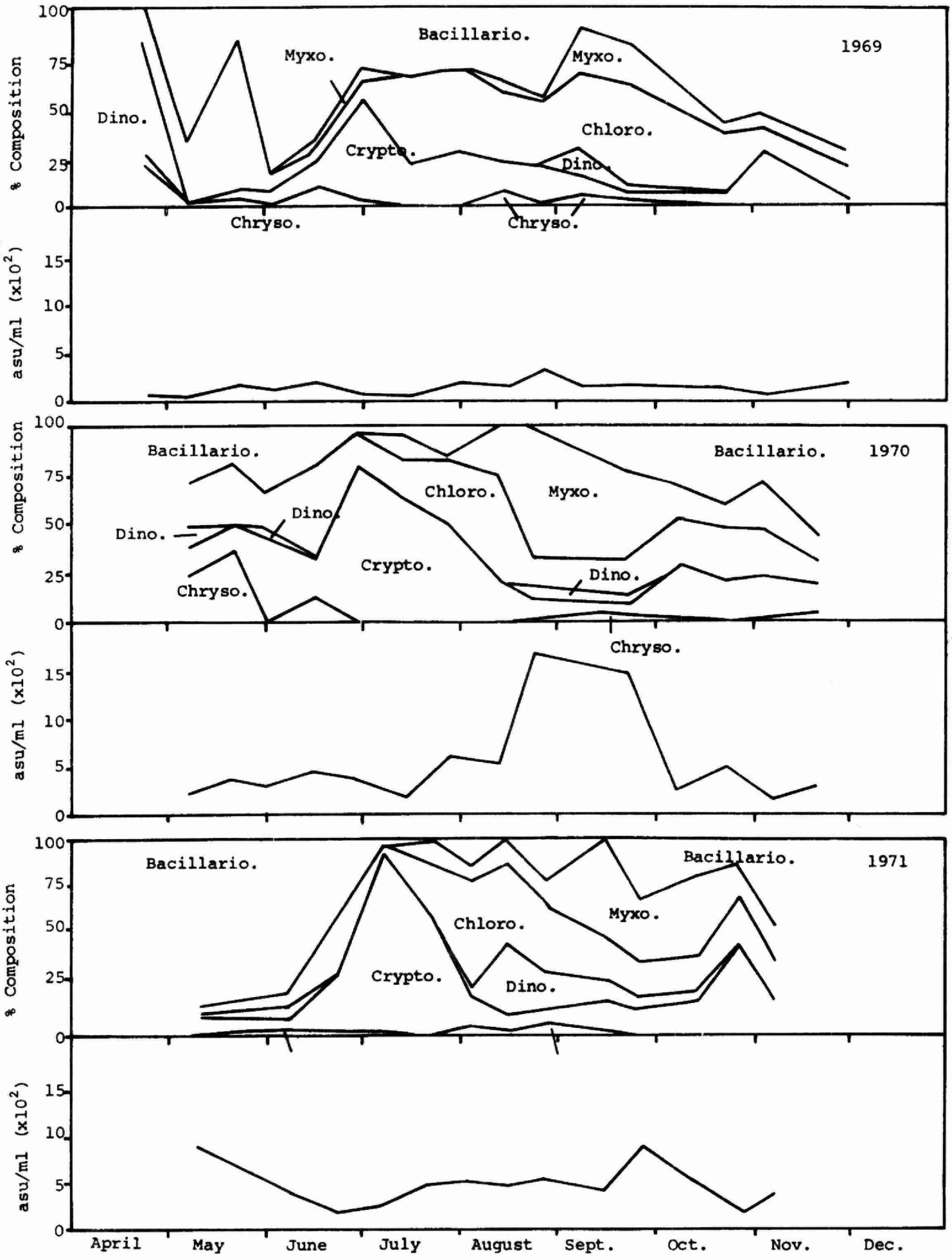
% Composition
asu/ml (x10²)
1969
Bacillario.
Myxo.
Dino.
Crypto.
Chloro.
Chryso.
1970
Bacillario.
Chloro.
Myxo.
Dino.
Crypto.
Chryso.
1971
Bacillario.
Chloro.
Myxo.
Crypto.
Dino.
Chryso.
April
May
June
July
August
Sept.
Oct.
Nov.
Dec.

Figure 9: Seasonal Changes in phytoplankton abundance and species composition at Station 1040 in the Nanticoke area of Lake Erie. Data are presented for 1971 only.

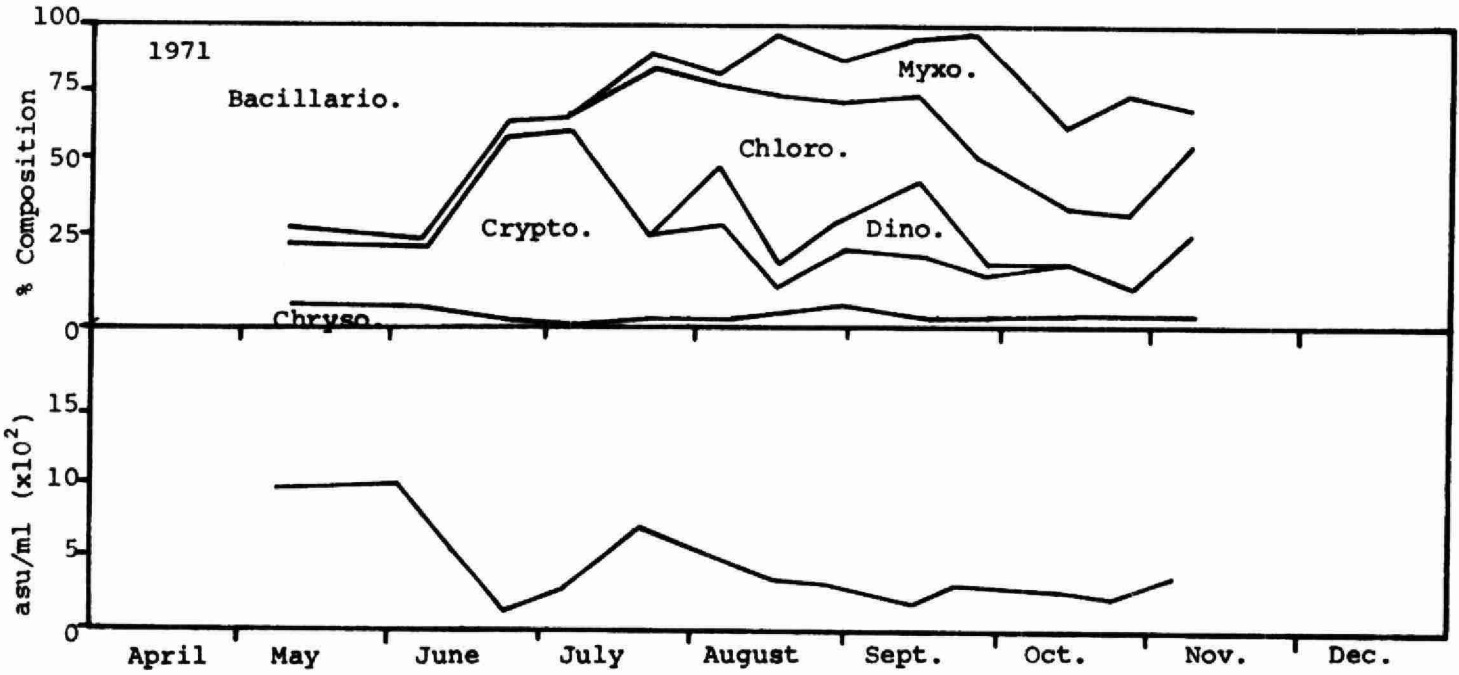
1971
Bacillario.
Myxo.
Chloro.
Crypto.
Dino.
Chryso.
% Composition
100
75
50
25
0
asu/ml (x10²)
15
10
5
0
April
May
June
July
August
Sept.
Oct.
Nov.
Dec.

Table 1: Phytoplankton data from nine sampling locations in the Nanticoke area of Lake Erie. All values are expressed in areal standard units per millilitre and represent maximum numbers attained.

Species	Date		In-shore stations						Off-shore stations		
			518	810	994	1008	1016	1040	112	501	648
BACILLARIOPHYCEAE											
Asterionella formosa Hass.	May - mid June	1969	18	18	20	28	29		10	22	54
		1970	11	23	40	11	12		14	19	24
		1971	25	104	72	32	26	56	20	2	28
	Mid June-July	1969	14	12	5	10	29		2	-	13
		1970	-	-	-	26	-		29	38	4
		1971	20	23	4	5	8	56	4	-	8
	Aug.-Sept.	1969	9	7	2	10	9		1	4	9
		1970	-	32	21	-	22		4	14	-
		1971	6	23	15	9	6	10	3	3	2
	Oct.-Nov.	1969	9	6	14	8	1		-	8	10
		1970	101	163	138	96	124		95	31	110
		1971	109	44	15	22	68	64	8	47	52
Diatoma elongatum (Lyngb.) Ag.	May-mid June	1969	24	18	27	5	28		-	47	-
		1970	21	34	-	50	20		5	-	9
		1971	-	-	3	-	-	-	-	-	-
	Mid-June-July	1969	-	-	-	-	1		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	1	-	-	1		-	-	-
	Aug.-Sept.	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-		-	-	-
	Oct.-Nov.	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	1	-	-	-	1	-	-	-

Table 1 - Continued

Species	Date	In-shore stations						Off-shore stations		
		518	810	994	1008	1016	1040	112	501	648
Fragilaria capucina Desm.	May-mid June 1969	-	32	-	11	16		22	-	5
	1970	89	38	45	-	62		-	6	29
	1971	-	184	-	-	-	-	-	-	43
	Mid June-July 1969	-	7	-	-	16		-	-	13
	1970	-	14	-	-	77		-	-	114
	1971	-	-	-	-	1	-	9	-	226
	Aug.-Sept. 1969	-	-	23	-	-		-	-	-
	1970	-	-	-	-	-		-	-	-
	1971	-	-	-	-	-	-	-	-	77
	Oct.-Nov. 1969	16	34	-	22	-		3	38	9
	1970	121	58	-	98	-		-	17	25
	1971	-	46	139	-	71	-	-	-	-
Fragilaria crotonensis Kitton	May-mid June 1969	1	72	-	15	7		-	-	-
	1970	82	-	107	-	61		2	-	-
	1971	-	15	43	-	296	-	-	-	-
	Mid June-July 1969	204	44	98	298	54		35	17	35
	1970	95	114	351	81	90		42	64	26
	1971	91	165	129	83	188	-	50	27	33
	Aug.-Sept. 1969	102	146	98	298	152		64	65	205
	1970	632	343	753	794	530		169	598	559
	1971	-	165	129	141	217	-	121	-	20
	Oct.-Nov. 1969	-	12	-	38	29		-	19	15
	1970	485	242	41	302	41		73	38	120
	1971	191	30	78	71	89		69	42	52

Table 1: Continued

Species	Date		In-shore Stations 518	810	994	1008	1016	1040	Off-shore Stations 112	501	648
Fragilaria spp.	May - mid June	1969	233	-	1075	223	37	-	-	140	23
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	1685	213	-	386	-
	Mid - June-July	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	270	765	-	-	-	60	187	-	-
	Aug.-Sept.	1969	-	5	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	203	-
		1971	149	-	-	-	-	143	28	-	149
	Oct. - Nov.	1969	-	-	180	66	163	-	13	67	-
		1970	-	3	-	-	-	-	-	-	-
		1971	27	312	-	43	-	81	8	7	-
Melosira Binderna Kütz.	May-mid June	1969	110	28	24	101	34	-	100	27	72
		1970	118	58	58	79	40		129	78	267
		1971	101	42	36	10	139	215	132	52	47
	Mid June-July	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	7	-	-	-	-	-	-	-
	Aug. - Sept.	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Oct. - Nov.	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	-	-	-	-

Table 1:continued

	Date		In-shore Stations						Off-shore Stations		
			518	810	994	1008	1016	1040	112	501	648
Stephanodiscus astraea (Ehr.) Grun.	May - mid June	1969	-	23	-	-	38	-	-	-	6
		1970	-	22	51	-	30	-	20	63	58
		1971	-	-	-	-	-	9	-	-	-
	Mid June - July	1969	5	7	-	26	38	-	-	-	6
		1970	2	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	8	-	-	-
	Aug. - Sept.	1969	7	6	7	26	7	-	-	4	-
		1970	-	97	-	-	19	-	-	-	-
		1971	-	-	-	-	-	10	-	-	-
	Oct. - Nov.	1969	156	206	222	149	175	-	89	58	112
		1970	62	24	45	115	71	-	15	120	19
		1971	37	86	27	25	86	72	21	97	63
Stephanodiscus spp.	May - mid June	1969	53	16	28	45	27	-	7	17	36
		1970	21	22	7	26	8	-	12	24	25
		1971	96	112	145	10	541	109	136	215	62
	Mid June-July	1969	-	-	-	7	22	-	5	-	-
		1970	-	-	-	-	-	-	-	1	2
		1971	115	38	1	-	3	19	1	-	2
	Aug. - Sept.	1969	-	-	-	-	7	-	7	-	-
		1970	-	2	17	1	1	-	3	-	3
		1971	-	38	1	22	22	-	4	-	1
	Oct. - Nov.	1969	-	-	-	-	-	-	12	-	22
		1970	8	56	8	-	112	-	6	4	5
		1971	70	6	32	4	4	13	66	4	30

Table 1. continued.

	Date		In-shore Stations						Off-shore Stations		
			518	810	994	1008	1016	1040	111	501	648
Synedra spp.	May - mid June	1969	-	57	36	12	61	-	19	48	-
		1970	54	50	33	53	47	-	25	24	30
		1971	4	31	15	11	25	23	37	72	33
	Mid June-July	1969	-	2	1	1	61	-	-	-	3
		1970	6	5	-	5	-	-	-	-	11
		1971	43	45	2	24	24	13	21	-	14
	Aug. - Sept.	1969	2	-	1	1	-	-	-	1	1
		1970	-	9	-	14	4	-	1	-	1
		1971	4	3	2	4	6	2	-	3	1
	Oct. - Nov.	1969	-	-	-	-	-	-	12	-	22
		1970	8	56	8	-	112	-	6	4	5
		1971	70	6	32	4	4	13	66	4	30
Tabellaria fenestrata (Lyngb.) Kütz.	May - mid June	1969	157	80	46	36	97	-	23	7	3
		1970	-	2	-	20	-	-	-	-	-
		1971	36	35	-	-	-	38	-	-	-
	Mid June-July	1969	29	39	21	61	97	-	10	7	73
		1970	-	-	-	-	-	-	-	-	-
		1971	114	7	-	-	-	1	13	169	-
	Aug. - Sept.	1969	14	18	10	61	9	-	10	22	8
		1970	-	-	-	-	-	-	-	-	-
		1971	3	4	-	-	27	-	-	13	7
	Oct. - Nov.	1969	17	20	24	15	18	-	5	11	9
		1970	-	-	-	11	24		17	8	-
		1971	-	-	10	-	-	-	-	-	-

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
CHLOROPHYCEAE											
Ankistrodesmus spp.	May-mid June	1969	1	6	5	10	-		7	2	2
		1970	2	3	1	2	2		14	21	5
		1971	17	19	11	13	17	16	18	8	13
	Mid June-July	1969	1	1	1	1	5		-	-	2
		1970	1	1	2	4	1		-	5	-
		1971	15	8	3	21	3	8	1	3	5
	Aug.-Sept.	1969	3	6	1	6	1		1	2	4
		1970	3	1	4	-	-		-	1	1
		1971	4	2	3	3	3	4	2	2	2
	Oct.-Nov.	1969	4	6	38	10	7		2	5	2
		1970	4	6	3	5	4		3	2	8
		1971	3	2	1	2	4	7	2	1	-
Chlamydomonas spp.	May-mid June	1969	13	33	46	64	12		44	185	112
		1970	211	127	138	81	203		156	95	162
		1971	2	8	14	1	9	3	26	20	4
	Mid-June-July	1969	11	1	13	1	-		1	-	2
		1970	83	107	33	79	97		26	34	28
		1971	16	11	5	4	3	-	5	11	8
	Aug.-Sept.	1969	3	4	3	11	5		3	12	4
		1970	27	44	63	94	67		34	26	36
		1971	5	7	4	5	5	10	9	9	7
	Oct.-Nov.	1969	7	7	19	6	9		18	5	7
		1970	4	11	6	11	12		8	16	14
		1971	9	4	4	1	12	16	3	2	5

Table 1: Continued

Species	Date		In-shore stations						Off-shore stations		
			518	810	994	1008	1016	1040	112	501	648
Coelastrum spp.	May-mid June	1969	-	-	1	-	-		-	-	-
		1970	-	-	-	-	-		-	-	2
		1971	-	2	-	-	-		-	-	1
	Mid June-July	1969	27	9	1	16	27		22	7	6
		1970	-	8	12	-	8		-	7	-
		1971	8	4	4	-	7	5	23	1	3
	Aug.-Sept.	1969	12	12	11	15	19		12	4	6
		1970	6	13	-	33	5		4	5	-
		1971	-	15	25	44	18	15	18	35	-
	Oct.-Nov.	1969	-	35	18	-	-		-	-	6
		1970	9	3	7	3	6		3	4	9
		1971	11	8	18	14	13	-	8	6	15
Cosmarium spp.	May-mid June	1969	-	20	-	-	-		-	-	-
		1970	3	-	-	-	-		-	2	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	19	5	12	8	15		5	-	-
		1970	9	15	28	-	14		6	13	-
		1971	-	2	-	-	26	-	-	-	-
	Aug.-Sept.	1969	9	22	23	23	11		27	15	29
		1970	31	15	7	21	29		-	18	26
		1971	19	26	12	-	73	41	45	101	38
	Oct.-Nov.	1969	-	15	12	6	-		6	9	22
		1970	3	19	16	13	3		10	16	-
		1971	16	3	-	-	21	32	-	-	-

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
Oedogonium spp.	May-mid June	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	-	-	-	-	-		-	-	-
		1970	71	114	46	93	145		288	263	46
		1971	-	74	-	-	-	286	-	133	5
	Aug.-Sept.	1969	6	-	-	-	-		-	-	5
		1970	94	66	-	-	25		-	7	-
		1971	-	-	-	-	-	-	24	-	-
	Oct.-Nov.	1969	-	-	-	-	10		-	10	17
		1970	7	-	4	14	-		2	59	-
		1971	-	-	17	-	-	13	-	-	-
Oocystis spp.	May-mid June	1969	-	8	-	5	-		1	-	1
		1970	-	-	-	-	-		-	-	-
		1971	-	-	1	6	-	-	1	-	22
	Mid June-July	1969	44	12	69	73	37		60	4	40
		1970	60	75	7	83	79		38	100	84
		1971	43	42	14	3	27	64	39	35	-
	Aug.-Sept.	1969	36	46	54	93	26		19	27	31
		1970	113	87	42	78	97		54	61	87
		1971	156	263	181	136	202	167	86	93	59
	Oct.-Nov.	1969	1	5	18	5	1		3	2	6
		1970	7	13	19	9	12		13	41	9
		1971	11	10	4	16	52	5	26	8	4

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
Pediastrum spp.	May-mid June	1969	-	1	1	-	-		-	-	-
		1970	-	-	-	-	8		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	4	5	25	35	15		-	3	3
		1970	-	3	-	-	-		-	-	-
		1971	83	11	-	-	-	19	-	-	-
	Aug.-Sept.	1969	15	38	12	11			16	8	
		1970	17	197	25	121	27		33	193	332
		1971	40	31	11	144	9	43	136	9	4
	Oct.-Nov.	1969	21	99	84	13	17		4	18	12
		1970	12	12	27	49	103		33	61	5
		1971	307	71	82	27	22	14	1	6	10
Scenedesmus spp.	May-mid June	1969	1	3	7	1	-		2	4	2
		1970	10	6	4	4	2		7	5	4
		1971	19	3	11	2	2	3	5	-	5
	Mid June-July	1969	3	16	1	-	3		1	3	2
		1970	4	7	1	2	6		7	4	-
		1971	4	4	1	5	6	5	1	3	-
	Aug.-Sept.	1969	4	2	1	5	5		4	1	1
		1970	4	9	22	17	7		-	6	7
		1971	19	14	13	12	13	2	10	24	2
	Oct.-Nov.	1969	2	8	10	5	12		2	9	2
		1970	4	2	4	10	8		2	3	6
		1971	13	9	16	7	25	22	1	2	33

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
Schroederia spp.	May-mid June	1969	3	-	1	4	3		3	22	5
		1970	12	14	16	13			29	25	17
		1971	-	-	-	-	-	-	-	18	-
	Mid June-July	1969	-	6	2	-	-		2	-	-
		1970	4	3	2	-	5		21	189	4
		1971	-	-	-	-	-	-	-	-	-
	Aug.-Sept.	1969	-	-	-	1	-		-	-	-
		1970	41	2	1	7	1		2	1	1
		1971	-	-	-	-	-	-	1	-	-
	Oct.-Nov.	1969	-	1	1	3	-		1	-	3
		1970	3	2	-	1	-		1	1	2
		1971	-	-	-	-	2	-	-	-	-
Sphaerogcystis schroeteri Chodat	May-mid June	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	4	-	-	-	6		-	-	-
		1970	26	-	77	21	75	-	57	189	16
		1971	57	2	-	4	-		1	1	1
	Aug.-Sept.	1969	13	20	10	9	3		11	11	50
		1970	43	49	25	83	29		93	69	57
		1971	-	43	219	21	27	39	62	23	10
	Oct.-Nov.	1969	-	-	5	-	-		8	8	-
		1970	-	16	2	9	4		48	4	1
		1971	33	2	-	1	10	31	3	-	-

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
CHRYSOPHYCEAE											
Dinobryon spp.	May-mid June	1969	72	27	188	17	12		3	28	60
		1970	83	32	102	130	116		4	140	61
		1971	41	58	75	22	24	11	45	31	20
	Mid-June-July	1969	7	-	-	-	2		32	6	36
		1970	19	18	14	2	10		5	20	13
		1971	24	7	-	-	2	6	8	2	30
	Aug.-Sept.	1969	10	18	22	16	34		10	11	10
		1970	37	30	52	32	-		26	25	24
		1971	48	31	20	36	40	23	12	12	12
	Oct.-Nov.	1969	-	-	31	3	7		-	1	1
		1970	-	9	65	11	38		26	-	6
		1971	-	-	-	5	14	7	4	3	-

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
CRYPTOPHYCEAE											
Cryptomonas spp.	May-mid June	1969	54	60	10	17	24		4	23	12
		1970	157	139	182	103	133		77	79	60
		1971	49	93	19	26	62	90	16	38	43
	Mid June-July	1969	353	554	147	370	50		109	25	57
		1970	276	300	303	240	287		192	228	138
		1971	184	95	50	111	142	200	302	36	33
	Aug.-Sept.	1969	96	54	61	102	83		28	31	33
		1970	132	83	77	160	90		69	57	94
		1971	97	245	81	70	71	111	105	276	38
	Oct.-Nov.	1969	11	8	33	27	13		7	6	18
		1970	94	48	63	59	95		65	101	46
		1971	103	80	27	36	42	34	45	41	61
Rhodomonas minuta Skuja	May-mid June	1969	-	164	-	11	137		-	-	4
		1970	65	85	91	39	1		110	45	38
		1971	87	91	49	25	252	122	100	185	44
	Mid June-July	1969	77	60	31	24	47		23	1	49
		1970	245	242	96	178	321		167	145	69
		1971	226	202	137	134	164	309	109	97	93
	Aug.-Sept.	1969	26	14	20	69	8		14	24	14
		1970	69	38	74	93	57		46	53	64
		1971	58	116	40	51	56	45	55	59	65
	Oct.-Nov.	1969	35	19	148	31	18		13	12	33
		1970	42	35	25	59	39		34	32	28
		1971	69	54	44	48	59	75	59	45	84

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
DINOPHYCEAE											
Ceratium hirundinella (O.Müll.) Dujardin	May-mid June	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	-	-	-	-	-		-	26	-
		1970	16	-	-	-			30	-	32
		1971	-	-	-	-	-	-	-	-	-
	Aug.-Sept.	1969	273	565	183	2266	223		97	87	33
		1970	109	126	134	78	76		26	32	115
		1971	187	231	199	100	160	104	119	263	40
	Oct.-Nov.	1969	-	-	6	-	16		33	-	-
		1970	-	-	28	-	5		24	16	22
		1971	-	118	15	-	-	-	61	27	-
Peridinium spp.	May-mid June	1969	8	35	26	-	4		-	22	-
		1970	15	12	12	11	7		-	8	3
		1971	-	62	74	32	200	78	89	180	132
	Mid June-July	1969	-	-	-	2	7		-	-	-
		1970	-	-	-	2	3		-	2	4
		1971	12	-	-	26	-	-	-	-	15
	Aug.-Sept.	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	8	-	2	2	-	3	-	6
	Oct.-Nov.	1969	6	-	3	4	-		-	5	-
		1970	-	-	-	-	2		2	-	1
		1971	-	-	-	-	-	15	-	13	7

Table 1: Continued

Species	Date		In-shore stations 518	810	994	1008	1016	1040	Off-shore stations 112	501	648
MYXOPHYCEAE											
Anabaena spp.	May-mid June	1969	-	-	-	-	-		-	-	-
		1970	11	-	-	11	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	-	9	-	-	-		-	-	-
		1970	-	11	-	-	-		-	-	5
		1971	-	6	12	-	-	-	-	-	-
	Aug.-Sept.	1969	12	-	-	38	15		20	-	13
		1970	117	29	28	64	81		44	53	47
		1971	96	92	20	31	29	26	43	87	17
	Oct.-Nov.	1969	5	10	-	23	5		13	-	-
		1970	23	16	-	78	11		16	-	22
		1971	-	13	-	-	18	30	19	11	-
Aphanizomenon flos-aquae (L.) Ralfs	May-mid June	1969	15	-	13	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	2	-	-	7	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	11	-	-	-
	Aug.-Sept.	1969	9	19	-	-	-		-	8	-
		1970	19	70	-	32	17		-	18	19
		1971	-	-	-	27	11	-	-	-	-
	Oct.-Nov.	1969	6	23	-	-	-		15	7	17
		1970	54	40	19	36	17		22	14	22
		1971	-	-	-	-	-	-	11	-	-

Table 1, continued

	Date		In-Shore Stations						Off-shore Stations		
			518	810	994	1008	1016	1040	112	501	648
Ashanocapsa spp.	May - mid June	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June -July	1969	-	-	63	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Aug.-Sept.	1969	12	74	-	38	15	-	20	-	13
		1970	117	29	28	54	40	-	44	53	47
		1971	96	92	20	31	29	26	43	87	17
	Oct.-Nov.	1969	-	14	-	28	-	-	-	50	26
		1970	-	42	32	15	25	-	95	-	11
		1971	-	30	-	-	-	50	-	-	-
Aphanothece spp.	May -mid June	1969	-	-	-	-	-	-	-	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	-	-	-	-	2	-	-	-
	Mid June-July	1969	2	-	-	-	-	-	12	-	-
		1970	-	-	-	-	-	-	-	-	-
		1971	-	26	-	-	-	-	-	-	-
	Aug.-Sept.	1969	13	-	8	-	-	-	12	22	-
		1970	783	2251	1190	600	1135	-	581	399	390
		1971	261	59	187	399	216	-	244	89	61
	Oct.-Nov.	1969	-	-	-	-	4	-	-	31	-
		1970	27	20	10	-	17	-	64	34	28
		1971	38	56	-	-	8	15	26	114	41

Table 1, continued.

	Date		In-shore Stations						Off-shore Stations		
			518	810	994	1008	1016	1040	112	501	648
Chroococcus spp.	May-mid June	1969	4	-	-	-	-		-	-	-
		1970	-	-	-	-	-		6	13	13
		1971	4	6	7	-	9	-	-	11	4
	Mid June-July	1969	-	-	-	-	3		-	-	-
		1970	-	-	48	3	19		-	-	4
		1971	30	7	-	-	16	11	-	-	-
	Aug.-Sept.	1969	-	93	8	20	35		20	24	22
		1970	53	65	98	160	18		51	61	31
		1971	89	74	116	39	141	74	52	96	49
	Oct.-Nov.	1969	-	-	-	-	-		-	-	-
		1970	30	8	12	12	8		12	9	-
		1971	-	59	20	-	164	13	-	23	-
Gomphosphaeria spp.	May-mid June	1969	-	-	-	-	-		-	-	-
		1970	-	-	-	-	-		-	-	-
		1971	-	-	-	-	-	-	-	-	-
	Mid June-July	1969	-	-	-	-	-		-	-	-
		1970	5	-	-	-	-		-	-	-
		1971	-	-	-	-	27	11	-	-	-
	Aug.-Sept.	1969	9	13	-	-	7		-	-	-
		1970	155	67	115	99	48		50	31	29
		1971	52	20	84	-	-	28	16	121	-
	Oct.-Nov.	1969	-	-	-	-	-		-	-	-
		1970	31	15	13	-	23		-	-	20
		1971	-	12	7	-	63	11	92	50	-